ENGINEERING GUIDE - 1

EG - 1

Relating to Earth Dams, Hazard Classes, Spillway Requirements, Detention Storage Requirements, and Rainfall Data.

KANSAS STATE BOARD OF AGRICULTURE

DIVISION OF WATER RESOURCES

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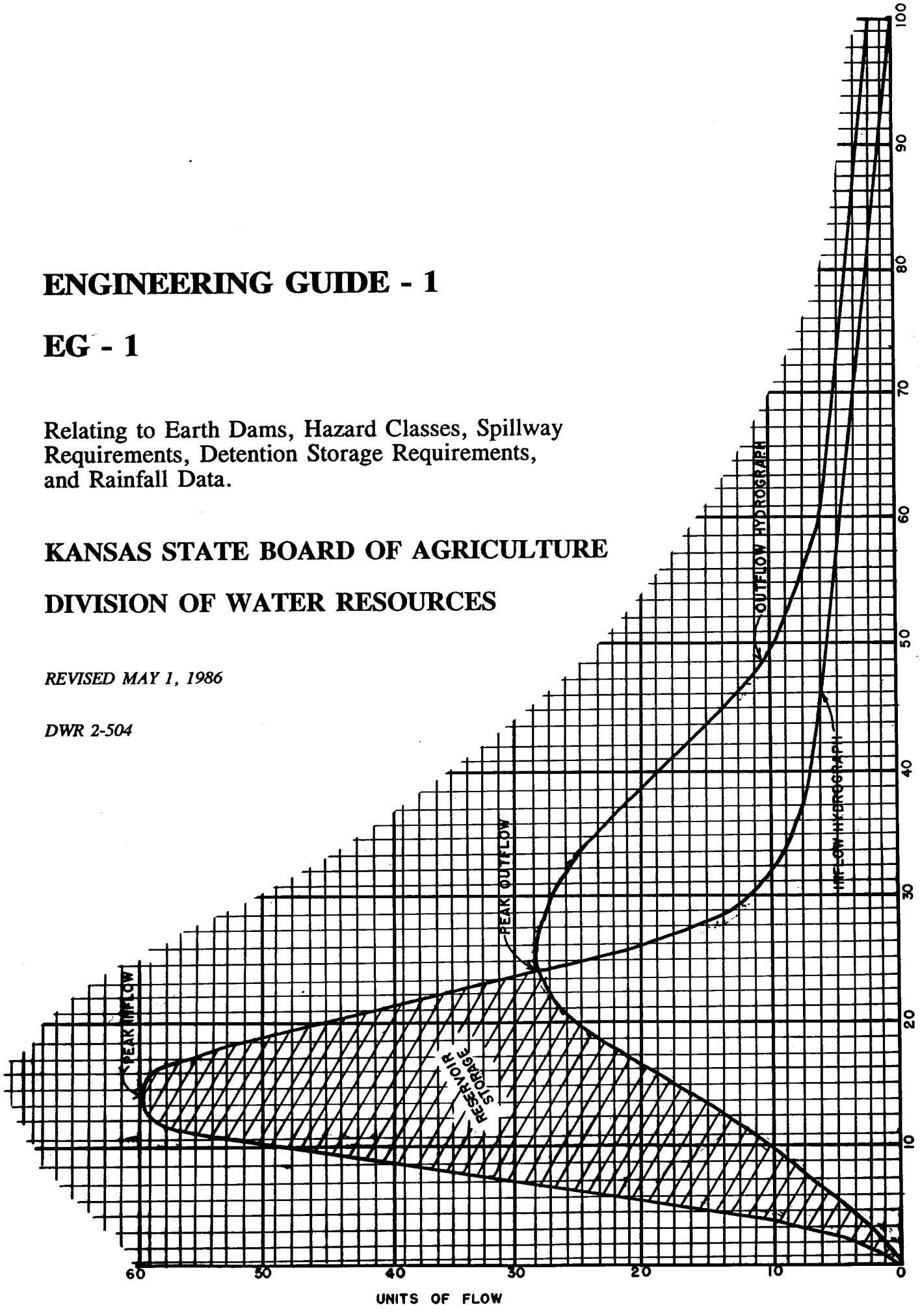

Table of Contents

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INTRODUCTION

These guidelines provide the general minimum hydrologic requirements of the Division of Water Resources for the design and construction of earthfill dams. The are not intended to constitute a test for design and construction. Final determination of the acceptability of design and adequacy of the plans and specifications will be made on an individual basis.

GENERAL

Plans and specifications for all dams which impound more than thirty acre-feet of water at the elevation of the top of the dam are required by K.S.A. 82a-301 to 305a to be submitted for permit and approval to the Chief Engineer of the Division of Water Resources. Plans and specifications for those dams which impound thirty acre-feet of water or less, for which tax reduction benefits are requested, are required by K.S.A. 82a-406 to be submitted for approval to the Chief Engineer of the Division of Water Resources. The address for mailing applications, plans and specifications is Chief Engineer, Division of Water Resources, 109 S.W. Ninth, Topeka, Kansas 66612-1283.

All plans and specifications for dams except size 1 with an "a" hazard classification shall be designed by a licensed professional engineer, competent in dam design and construction. A minimum of two sets of plans and specifications should be submitted with the application. The plans must be clearly legible prints (maximum size 24 inches by 36 inches) of the original tracings, capable of reproduction. Upon favorable consideration of the plans and specifications for a project, on set will be returned to the applicant; the second set will be retained in the office of the Chief Engineer. If additional approved sets of plans and specifications are desired by the applicant, the number required should be submitted for endorsement by the Chief Engineer.

DEFINITIONS

(a) Floodwater Retarding Dam – a single purpose dam designed for temporary storage of floodwater and for its controlled release.

(b) Grade Stabilization Structure – a structure designed to control the erosion of a water course.

(c) Height of Dam – the difference in elevation between the top of the dam and the original streambed on the centerline of the dam.

(d) Effective Height – the difference in elevation between the crest of the emergency spillway and the original streambed on the centerline of the dam.

(e) Effective Storage – the volume of the reservoir below the crest of the emergency spillway.

(f) Size Factor – the product of the Effective Height of Dam (in feet) by the Effective Storage (in acre-feet).

(g) Size of Dams:

(1) Those dams whose effective height is less than 25 feet; effective storage is less than 50 acre-feet; and size factor is less than 1,250.

(2) Those dams whose effective storage is greater than 50 acre-feet; and size factor is between 1,250 and 3,000.

(3) Those dams whose effective storage is greater than 50 acre-feet; and size factor is between 3,000 and 30,000.

(4) Those dams whose effective storage is greater than 50 acre-feet; and size factor is greater than 30,000.

(h) Hazard Classes of Dams:

Class (a) – Low Hazard – dams located in rural or agricultural areas where failure may damage farm buildings, limited agricultural land, or county, township and private roads.

Class (b) – Significant Hazard – dams located in predominantly rural or agricultural areas where failure may endanger few lives, damage isolated homes, secondary highways or minor railroads or cause interruption of use or service of relatively important public utilities.

Class (c) – High Hazard –dams located in areas where failure may cause extensive loss of life, and serious damage to homes, industrial and commercial facilities, important public utilities, main highways or railroads.

(i) Permanent Storage – the reservoir volume below the crest of the lowest ungated outlet.

(j) Detention Storage – the reservoir volume between the lowest ungated outlet and the crest of the emergency spillway.

(k) Freeboard – the vertical distance between the maximum reservoir stage attained in the event of the design rainfall and the top of the dam.

(l) Design Rainfall – the rainfall amount selected to determine the inflow hydrograph.

(m) P_2 – 2-year frequency, 6-hour duration precipitation, shown in Table No. 3.

(n) P_25 – 25 year frequency, 6-hour duration precipitation, shown in Table No. 3.

(o) P_50 – 50-year frequency, 6-hour duration precipitation, shown in Table No. 3.

(p) P_100 – 100 year frequency, 6-hour duration precipitation shown in Table No. 3.

(q) PMP - 6 – hour probable maximum precipitation, as shown in the attached Table No. 3.

(r) SCS – Soil Conservation Service, United State Department of Agriculture.

POLICIES

1. Commons hydrograph will be used for time-discharge relationship of reservoir inflow in the review of the adequacy of the emergency spillway.
2. Capacities of principal spillways in size 1 dams with barrel diameter equal to or greater than 18 inches and with an adequate trashrack my be considered in computing the adequacy of the emergency spillway and detention storage.
3. Capacities of principal spillways in size 2, 3, and 4 dams with a barrel diameter equal to or greater than 24 inches and with an adequate trashrack my be considered in computing the adequacy of the emergency spillway and detention storage.
4. SCS hydrologic methods using Antecedent Moisture Condition II (AMC II) will be used in determining the rainfall-runoff relationship in computing detention storage requirements.
5. SCS hydrologic methods using Antecedent Moisture Conditions shown in Fig. 2 will be used in determinING the rainfall-runoff relationship in sizing the emergency spillway.
6. A 6-hour storm duration will be used in all cases.
7. Time concentration (t_c) will be determined by the Kirpich nomograph, Figure 1, for drainage areas up to 3 square miles. For greater drainage areas, other empirical methods may be used.
8. Unit peak discharge (q) will be determined by the attached Table 1 or by other empirical methods derived from regional studies if approved by the Division.
9. Structures having floodwater retarding protection of an agricultural area as a primary purpose will have sufficient detention storage to store the computed runoff from a 25-year frequency (4% chance), 6-hour rainfall, using AMC II, without emergency spillway flow.

Structures having floodwater retarding protection of an urban area as a primary purpose will have sufficient detention storage to store the computed runoff from a 50-year frequency (2% chance), 6-hour rainfall, using AMC II, without emergency spillway flow.

10. Structures having grade stabilization as the primary purpose need not meet the requirements of minimum floodwater retarding protection for either rural or urban areas.
11. The design frequency of use of earth channel emergency spillways shall not exceed one in two years.
12. Dams classified in the attached Table No. 2 as 1(a), 1(b), 2(a), or 2(b) shall be designed on the basis of maximum inflow equals maximum emergency spillway outflow except where detention storage exceeds the 2-year storm or other conditions exist for which special consideration is necessary. Those which exceed the 2-year detention and, all other classes of dams may be designed by floodrouting, giving consideration to detention storage, emergency spillway capacity, and principal spillway capacity if the barrel diameter equals or exceeds 18 inches in size 1 dams and 24 inches in size 2, 3, and 4 dams.
13. The minimum design criteria for municipal and industrial water supply dams shall be the detailed in this guide for hazard class b dams.
14. Dams located on public road rights-of-way shall have principal and emergency spillways which meet the design requirements in the attached table. In addition to normal hazard classification criteria, daily vehicular traffic will also be considered, as follows:

Vehicles per day	Minimum Hazard
0 to 100	(a)
101 to 500	(b)
More than 500	(c)

15. The maximum velocities considered to be safe against erosion in various materials is as follows:

Material	Velocity (ft/sec.)
Sand	1.0
Sandy loam	2.0
Firm loam	3.0
Stiff clay loam	4.0
Stratified rock	8.0
Sound rock	13.0
Concrete	20.0

Emergency spillway grades and allowable velocities shall be approved on project by project basis by the Division.

16. The maximum velocities considered permissible in vegetated spillways are as fellows:

PERMISSIBLE VELOCITIES (FT/S)

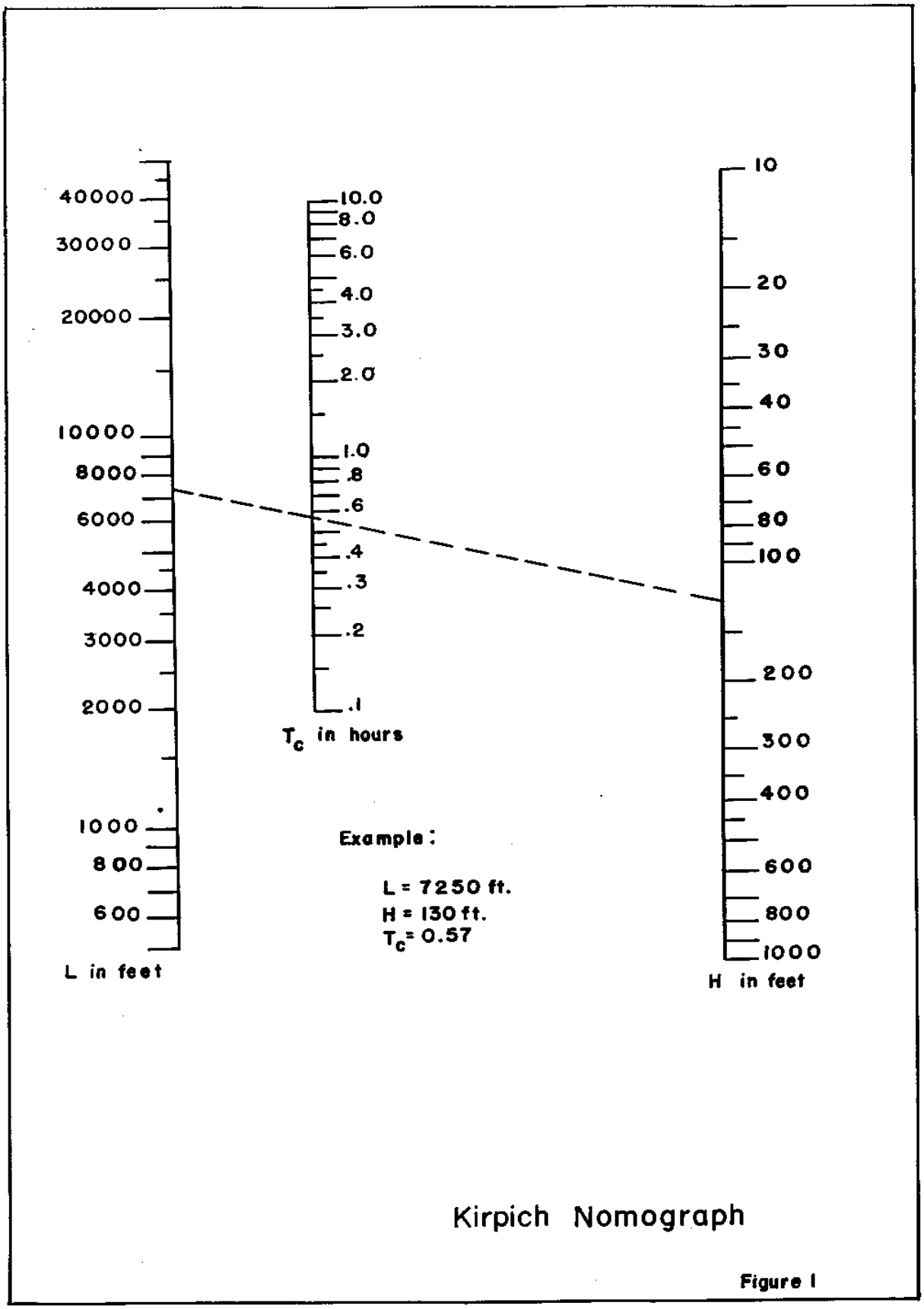
	Erosin Resistant Soils 2/		Easily Erodible Soils 3/	
Slope of exit channel in percent	0 to 5	5 to 10	0 to 5	5 to 10
Type of Vegetation	Permissible velocity 1/ feet per second			
Bermudagrass Bahiagrass	8	7	6	5
Buffalograss, Kentucky blue- Smooth brome- grass, Tall fescue, Reed canarygrass	7	6	5	4
Sod forming grass-legume mixtures	5	4	4	3
Lespedeza sericea, Weeping lovegrass, Yellow bluestem, Native grass mixtures	3.5	3.5	2.5	2.5

Adapted from Table 7-1, SCS TR-60.

1/ Increase values 10 percent when the anticipated average use of the spillway is not more frequent than once in 50 years or 25 percent when the anticipated average use is not more frequent than once in 100 years.

2/ Those with a high clay content and plasticity. Typical soil textures are silty clay, sandy clay and clay.

3/ Those with a high content of fine sand or silt and low or no plasticity. Typical soil textures are fine sand, silt, sandy loam and silty loam.



Kirpich Nomograph

Figure 1

Table 1. PEAK RATE

Unit Peak Discharge versus Time of Concentration

Tc (hours)	q cfs/(mi^2)/(in.)[1/]	Tc (hours)	q cfs/(mi^2)/(in.)[1/]
0.10	680	0.5	335
0.12	620	0.6	310
0.14	580	0.7	290
0.16	550	0.8	275
0.18	520	0.9	260
0.20	500	1.0	245
0.22	480	1.2	230
0.24	460	1.4	215
0.26	440	1.6	200
0.28	430	1.8	190
0.30	420	2.0	180
0.32	410	2.5	160
0.34	400		
0.36	390	3.0	145
0.38	380	3.5	130
0.40	370	4.0	120
0.42	360	4.5	110
0.44	350		
0.46	345	5.0	100
0.48	340	5.5	95
		6.0	90

1/ (in)-inch runoff

TABLE 2

SIZE	HAZARD CLASS	/1 MINIMUM DETENTION STORAGE	/2 PRECIPITATION FOR INFLOW HYDROGRAPH	MINIMUM * FREEBOARD	/4 MINIMUM EMERGENCY SPILLWAY DIMENSIONS	
					Depth	Width
(1) Eff Storage < 50 ac ft; Eff Height < 25 ft; Factor < 1250	a	Volume of runoff from P_2, or 18" elevation difference /3, whichever is greater.	P_{50}	1	3	20
	b		0.25 PMP	2		
	c		0.40 PMP	3		
(2) Eff Storage > 50 ac ft; Factor: 1,250 to 3,000	a	Volume of runoff from P_2, or 18" elevation difference /3, whichever is greater.	P_{100}	2	3	30
	b		0.25 PMP	2		
	c		0.40 PMP	3		
(3) Eff Storage > 50 ac ft; Factor: 3,000 to 30,000	a	Volume of runoff from P_2, or 24" elevation difference /3, whichever is greater.	P_{100}	3	5	40
	b		0.30 PMP	3		
	c		0.40 PMP	3		
(4) Eff Storage > 50 ac ft; Factor > 30,000	a	Volume of runoff from P_2, or 30" elevation difference /3, whichever is greater.	0.25 PMP	3	5	40
	b		0.30 PMP	3		
	c		0.40 PMP	3		

/1 Where flood control is one of the primary purposes of a structure, the minimum detention storage shall be as follows:
(a) Rural protection--detention of runoff from 25-year frequency, 6-hour rainfall, using AMC II.
(b) Urban protection--detention of runoff from 50-year frequency, 6-hour rainfall, using AMC II.
In all cases, AMC II will be used in computing minimum detention storage.

/2 In all cases, AMC in Figure 2 will be used in computing runoff for inflow hydrograph

/3 Elevation difference is vertical distance between crests of principal and emergency spillways.

/4 Structures without emergency spillways will require special consideration.

* DWR may require greater than minimum freeboard dependent on the individual site conditions.

TABLE 3

EXPECTED 6-HOUR STORM RAINFALL IN INCHES

Source: USWB TP-40 and NWS HR-51

	STORM FREQUENCY				
COUNTY	2 YR.	25 YR.	50 YR.	100 YR.	PMP
Allen	2.7	4.8	5.4	6.1	28.0
Anderson	2.7	4.8	5.3	6.0	27.8
Atchison	2.6	4.5	5.1	5.7	27.2
Barber	2.4	4.4	5.0	5.7	27.3
Barton	2.3	4.1	4.8	5.3	26.6
Bourbon	2.7	4.8	5.4	6.0	28.1
Brown	2.5	4.4	5.0	5.6	27.0
Butler	2.6	4.7	5.3	6.0	27.7
Chase	2.6	4.6	5.2	5.9	27.5
Chautauqua	2.7	4.9	5.5	6.2	28.3
Cherokee	2.8	5.0	5.5	6.2	28.5
Cheyenne	1.8	3.4	3.8	4.3	24.7
Clark	2.2	4.1	4.7	5.3	26.7
Clay	2.5	4.3	5.0	5.5	26.8
Cloud	2.4	4.2	4.8	5.4	26.6
Coffey	2.7	4.7	5.3	6.0	27.8
Comanche	2.3	4.2	4.9	5.5	27.0
Cowley	2.6	4.8	5.4	6.1	28.0
Crawford	2.8	4.9	5.4	6.1	28.3
Decatur	1.9	3.6	4.2	4.6	25.3
Dickinson	2.5	4.4	5.1	5.6	27.1
Doniphan	2.5	4.5	5.0	5.6	27.0
Douglas	2.6	4.6	5.2	5.8	27.5
Edwards	2.2	4.1	4.7	5.3	26.7
Elk	2.7	4.8	5.4	6.1	28.1
Ellis	2.1	3.9	4.6	5.0	26.2
Ellsworth	2.3	4.2	4.9	5.4	26.7
Finney	2.0	3.8	4.3	4.8	26.8
Ford	2.1	4.0	4.6	5.1	26.4
Franklin	2.7	4.7	5.2	5.9	25.8
Geary	2.5	4.4	5.1	5.7	27.1
Gove	2.0	3.7	4.3	4.7	25.7
Graham	2.0	3.8	4.4	4.8	25.8
Grant	1.9	3.7	4.2	4.7	25.6
Gray	2.0	3.9	4.4	4.9	26.1

TABLE 3 (continued).

TABLE 3

EXPECTED 6-HOUR STORM RAINFALL IN INCHES

Source: USWB TP-40 and NWS HR-51

	STORM FREQUENCY				
COUNTY	2 YR.	25 YR.	50 YR.	100 YR.	PMP
Greeley	1.8	3.4	3.9	4.4	25.0
Greenwood	2.7	4.8	5.3	6.1	27.8
Hamilton	1.8	3.5	4.0	4.5	25.2
Harper	2.5	4.5	5.2	5.9	27.5
Harvey	2.5	4.5	5.1	5.8	27.4
Haskell	2.0	3.8	4.3	4.8	25.9
Hodgeman	2.1	3.9	4.5	5.0	26.3
Jackson	2.6	4.5	5.1	5.7	27.2
Jefferson	2.6	4.6	5.1	5.8	27.3
Jewell	2.3	4.0	4.7	5.1	26.3
Johnson	2.6	4.6	5.2	5.8	27.5
Kearny	1.9	3.6	4.1	4.6	25.5
Kingman	2.4	4.4	5.1	5.7	27.3
Kiowa	2.2	4.2	4.8	5.4	26.7
Labette	2.8	5.0	5.5	6.2	28.4
Lane	2.0	3.7	4.3	4.8	25.8
Leavenworth	2.6	4.6	5.1	5.8	27.4
Lincoln	2.3	4.2	4.8	5.3	26.6
Linn	2.7	4.8	5.3	6.0	27.9
Logan	1.9	3.6	4.1	4.6	25.3
Lyon	2.6	4.6	5.2	6.0	27.5
McPherson	2.5	4.4	5.1	5.7	27.1
Marion	2.5	4.5	5.2	5.8	27.3
Marshall	2.5	4.3	4.9	5.5	26.8
Meade	2.1	4.0	4.6	5.1	26.3
Miami	2.7	4.7	5.2	5.9	27.7
Mitchell	2.3	4.1	4.7	5.2	26.4
Montgomery	2.8	5.0	5.5	6.2	28.3
Morris	2.6	4.5	5.1	5.8	27.3
Morton	1.9	3.6	4.1	4.6	25.4
Nemaha	2.5	4.4	5.0	5.6	26.9
Neosho	2.7	4.9	5.5	6.1	28.2
Ness	2.1	3.9	4.5	4.9	26.1
Norton	2.0	3.7	4.3	4.7	25.6
Osage	2.6	4.6	5.2	5.9	27.5

TABLE 3 (continued).

TABLE 3

EXPECTED 6-HOUR STORM RAINFALL IN INCHES

Source: USWB TP-40 and NWS HR-51

	STORM FREQUENCY				
COUNTY	2 YR.	25 YR.	50 YR.	100 YR.	PMP
Osborne	2.2	4.0	4.6	5.1	26.2
Ottawa	2.4	4.3	4.9	5.4	26.8
Pawnee	2.2	4.1	4.7	5.2	26.6
Phillips	2.1	3.8	4.4	4.9	25.8
Pottawatomie	2.5	4.4	5.0	5.6	27.0
Pratt	2.3	4.3	4.9	5.5	27.0
Rawlins	1.9	3.5	4.0	4.5	25.0
Reno	2.4	4.4	5.0	5.7	27.2
Republic	2.3	4.1	4.8	5.3	26.4
Rice	2.4	4.3	4.9	5.5	26.9
Riley	2.5	4.4	5.0	5.6	27.0
Rooks	2.1	3.9	4.5	4.9	26.0
Rush	2.2	4.0	4.6	5.1	26.4
Russell	2.2	4.1	4.7	5.2	26.5
Saline	2.4	4.3	5.0	5.5	26.9
Scott	1.9	3.6	4.2	4.7	25.5
Sedgwick	2.5	4.6	5.2	5.9	27.5
Seward	2.0	3.8	4.4	4.9	26.0
Shawnee	2.6	4.6	5.1	5.8	27.4
Sheridan	2.0	3.7	4.2	4.7	25.5
Sherman	1.8	3.4	3.9	4.4	24.8
Smith	2.2	3.9	4.6	5.0	26.1
Stafford	2.3	4.2	4.9	5.4	26.9
Stanton	1.9	3.6	4.1	4.5	25.3
Stevens	1.9	3.7	4.3	4.7	25.8
Sumner	2.6	4.7	5.3	6.0	27.8
Thomas	1.9	3.5	4.1	4.5	25.2
Trego	2.0	3.8	4.4	4.9	25.9
Wabunsee	2.6	4.5	5.1	5.8	27.3
Wallace	1.8	3.4	3.9	4.4	24.9
Washington	2.4	4.2	4.9	5.4	26.6
Wichita	1.9	3.5	4.1	4.5	25.3
Wilson	2.7	4.9	5.4	6.1	28.1
Woodson	2.7	4.8	5.4	6.1	28.0
Wyandotte	2.6	4.6	5.1	5.8	27.4

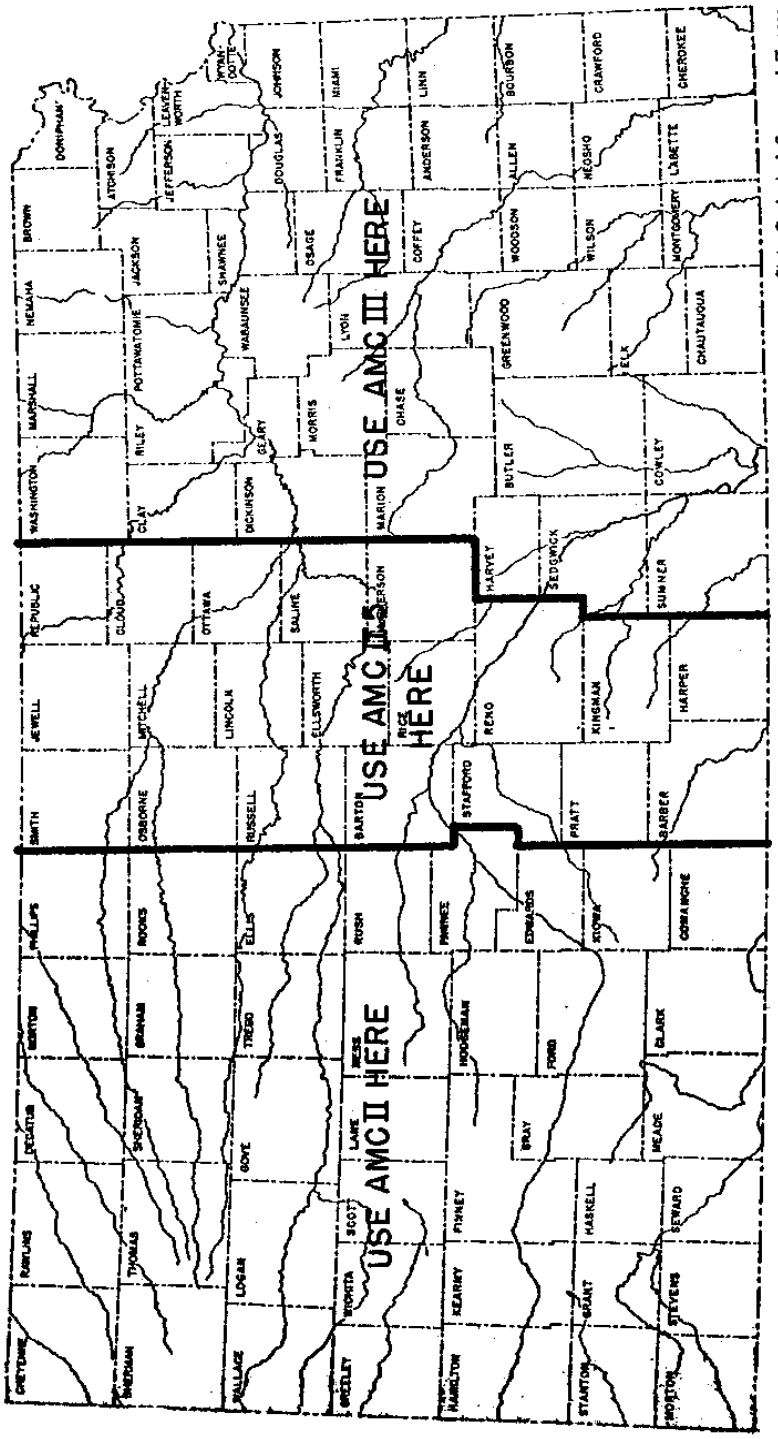


Figure 2. -- Antecedent Moisture Conditions for Hydrologic Design of Dams.